


# **Record Setting 2011 South Central/Southeast Montana Flooding**

2012 Montana Hydrology Workshop

Todd Chambers

Hydrology Focal Point

NWS Billings, MT

A large, multi-story wooden ark with a ramp on the left side. In the foreground, two giraffes stand on a paved path. To the right, there are some white animals, possibly sheep or goats, near a small waterfall. The ark is surrounded by greenery and a wooden fence.

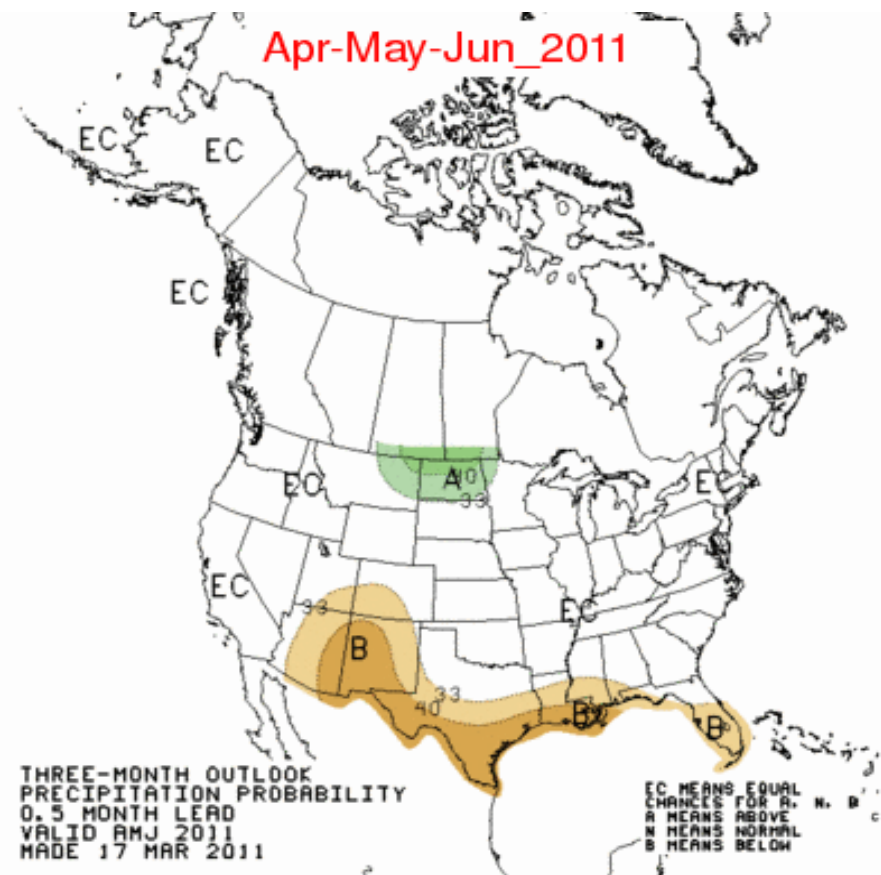
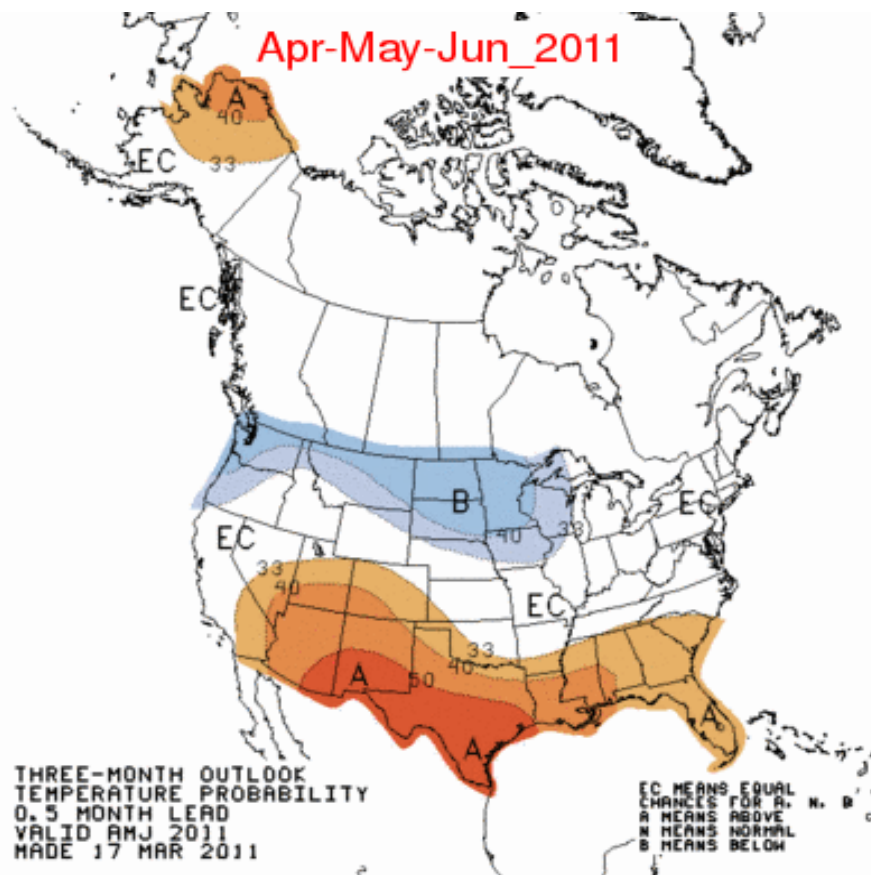
**The most Loaded Question toward  
the end of every Winter:**

**“So, Is it going to flood this Year?”**

Photo: Wall Street Journal

# Seasonal Outlook – March 2011

## La Nina



# April 1<sup>st</sup> 2011 Basin Average Snowpack

## (% April 1st Avg/% Avg Peak)

UPPER YELLOWSTONE RIVER BASIN		
Basin-wide percent of average	119	109
WIND RIVER BASIN (WYOMING)		
Basin-wide percent of average	104	95
SHOSHONE RIVER BASIN (WYOMING)		
Basin-wide percent of average	111	102
BIGHORN RIVER BASIN (WYOMING)		
Basin-wide percent of average	113	102
TONGUE RIVER BASIN (WYOMING)		
Basin-wide percent of average	108	95
POWDER RIVER BASIN (WYOMING)		
Basin-wide percent of average	117	102
LOWER YELLOWSTONE RIVER BASIN		
Basin-wide percent of average	109	98

NRCS Data

# Forecasts Heading into May

- La Nina On-going – Trends toward heavier spring snow in mountains.
- La Nina signal for lower elevations East of the Divide : Signal Mixed.
- CPC forecast for Equal Chances on Precipitation ...Leaning toward Colder Temperatures.
- Mountain snowpack at or slightly above average.
- **Overall a normal to slightly above normal runoff and flood season was anticipated.**



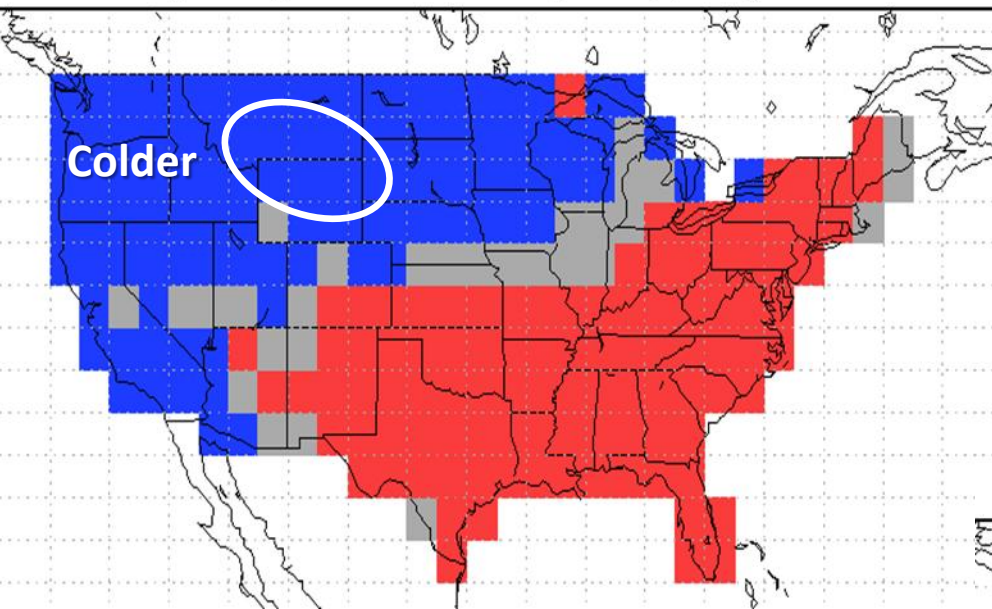


**Nothing looks too threatening as of  
March/ April**

**So What Happened?**

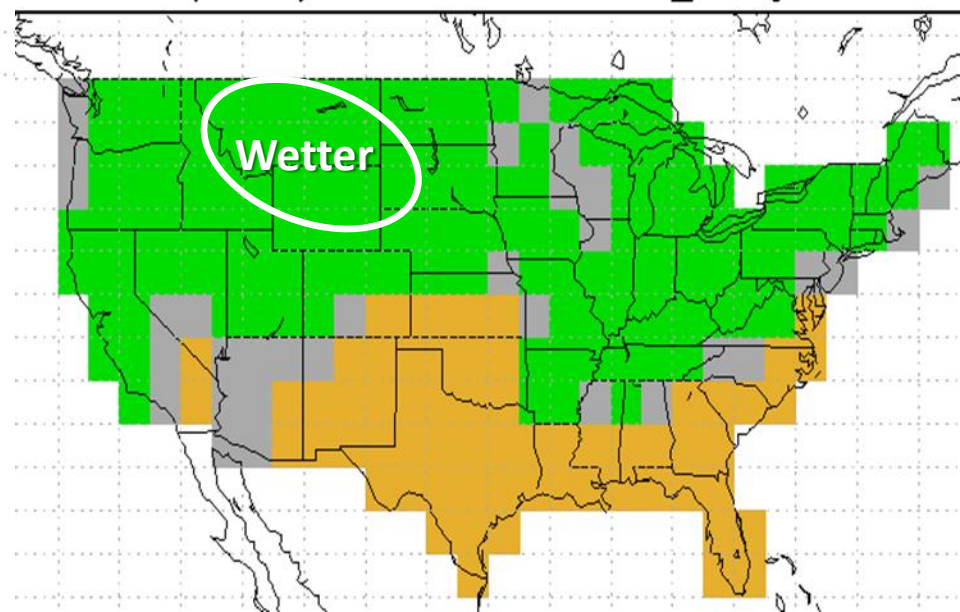
# CPC APR -> JUN Verification

Apr-May-Jun 2011 Temp Obs\_Categories



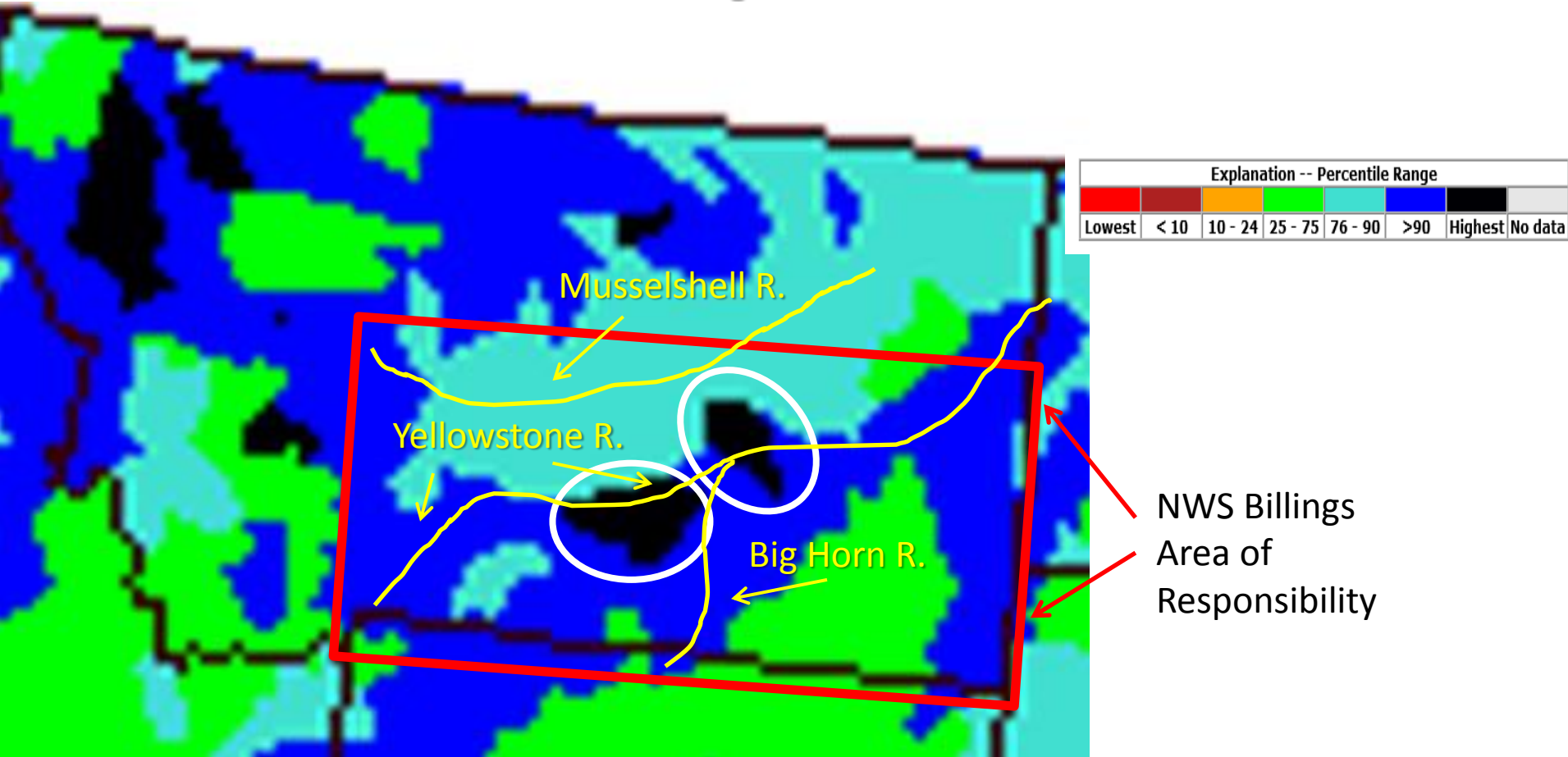
CPC Verification

Apr-May-Jun 2011 Prec Obs\_Categories





# 2011 Computed Runoff



Two large areas at the 99<sup>th</sup> percentile for yearly runoff



# Computed Runoff For Montana

Region	Year	Runoff (mm)	Runoff (in)	Rank	Percentile
MT	1949	123.17	4.93	70	37.50
MT	1950	157.87	6.31	30	73.21
MT	1951	177.03	7.08	14	87.50
MT	1952	150.45	6.02	36	67.86
MT	1953	138.11	5.52	49	56.25
MT	1954	148.57	5.94	39	65.18
MT	1955	131.61	5.26	58	48.21
MT	1956	156.66	6.27	32	71.43
MT	1957	135.93	5.44	51	54.46
MT	1958	117.09	4.68	78	30.36
MT	1959	159.42	6.38	27	75.89
MT	1960	135.27	5.41	53	52.68
MT	1961	111.14	4.45	82	26.79
MT	1962	136.61	5.46	50	55.36
MT	1963	126.07	5.04	64	42.86
MT	1964	150.96	6.04	34	69.64
MT	1965	179.69	7.19	10	91.07
MT	1966	122.78	4.91	72	35.71
MT	1967	163.84	6.55	24	78.57
MT	1968	141.58	5.66	45	59.82
MT	1969	160.56	6.42	26	76.79
MT	1970	149.31	5.97	37	66.96
MT	1971	177.32	7.09	13	88.39
MT	1972	176.74	7.07	15	86.61
MT	1973	104.01	4.16	97	13.39
MT	1974	169.63	6.79	20	82.14
MT	1975	174.73	6.99	16	85.71
MT	1976	170.79	6.83	19	83.04
MT	1977	80.88	3.24	108	3.57
MT	1978	148.80	5.95	38	66.07
MT	1979	125.40	5.02	67	40.18
MT	1980	110.79	4.43	85	24.11
MT	1981	132.56	5.30	55	50.89



Region	Year	Runoff (mm)	Runoff (in)	Rank	Percentile
MT	1982	146.62	5.86	40	64.29
MT	1983	118.66	4.75	75	33.04
MT	1984	125.67	5.03	66	41.07
MT	1985	106.39	4.26	94	16.07
MT	1986	133.86	5.35	54	51.79
MT	1987	95.27	3.81	102	8.93
MT	1988	83.06	3.32	105	6.25
MT	1989	110.35	4.41	86	23.21
MT	1990	129.46	5.18	60	46.43
MT	1991	141.06	5.64	46	58.93
MT	1992	88.59	3.54	104	7.14
MT	1993	115.27	4.61	79	29.46
MT	1994	98.74	3.95	99	11.61
MT	1995	123.56	4.94	69	38.39
MT	1996	183.89	7.36	7	93.75
MT	1997	193.21	7.73	4	96.43
MT	1998	127.45	5.10	62	44.64
MT	1999	130.84	5.23	59	47.32
MT	2000	104.98	4.20	96	14.29
MT	2001	72.49	2.90	111	0.89
MT	2002	110.87	4.43	84	25.00
MT	2003	98.46	3.94	100	10.71
MT	2004	90.23	3.61	103	8.04
MT	2005	101.89	4.08	98	12.50
MT	2006	117.54	4.70	77	31.25
MT	2007	108.92	4.36	89	20.54
MT	2008	132.12	5.28	57	49.11
MT	2009	124.22	4.97	68	39.29
MT	2010	114.92	4.60	80	28.57
MT	2011	214.82	8.59	1	99.11

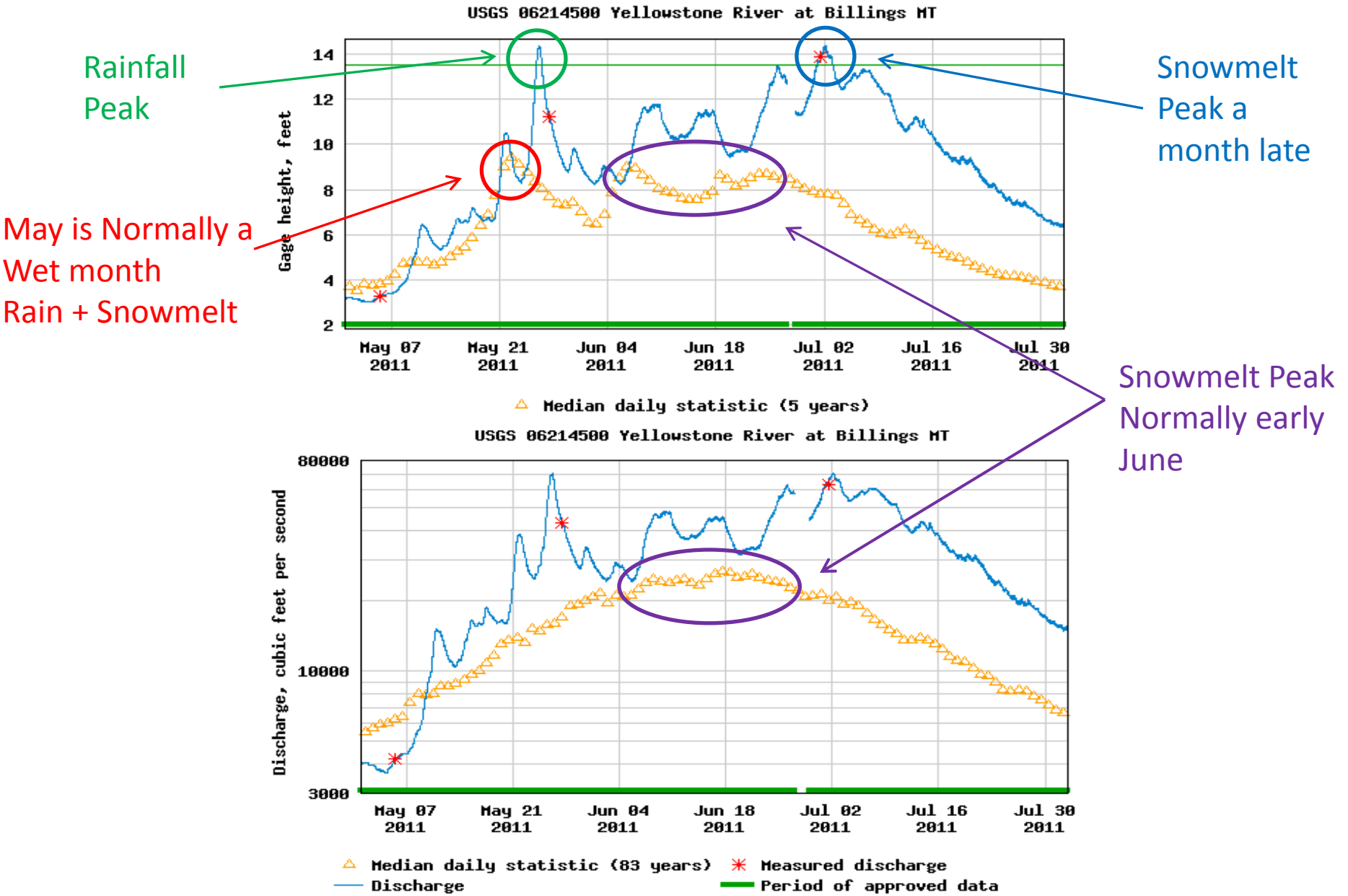
1997 →

2001 –  
Record Low →

← 1975

2011 –  
Record High →

# Representative of Area Gages



An aerial photograph showing a residential area severely affected by flooding. A river, likely the Yellowstone River, has overflowed its banks, inundating large areas of land. The floodwater is a murky, brownish-tan color. In the upper left, a large green field is partially submerged. To the right, a dense residential neighborhood with many houses is visible, some of which are surrounded by water. In the lower left, a large area of trees and shrubs is completely underwater. A road or bridge structure is visible in the lower center, partially submerged. The overall scene depicts significant property damage and displacement.

# Equals : Historic Flooding

Photo : Billings  
Gazette





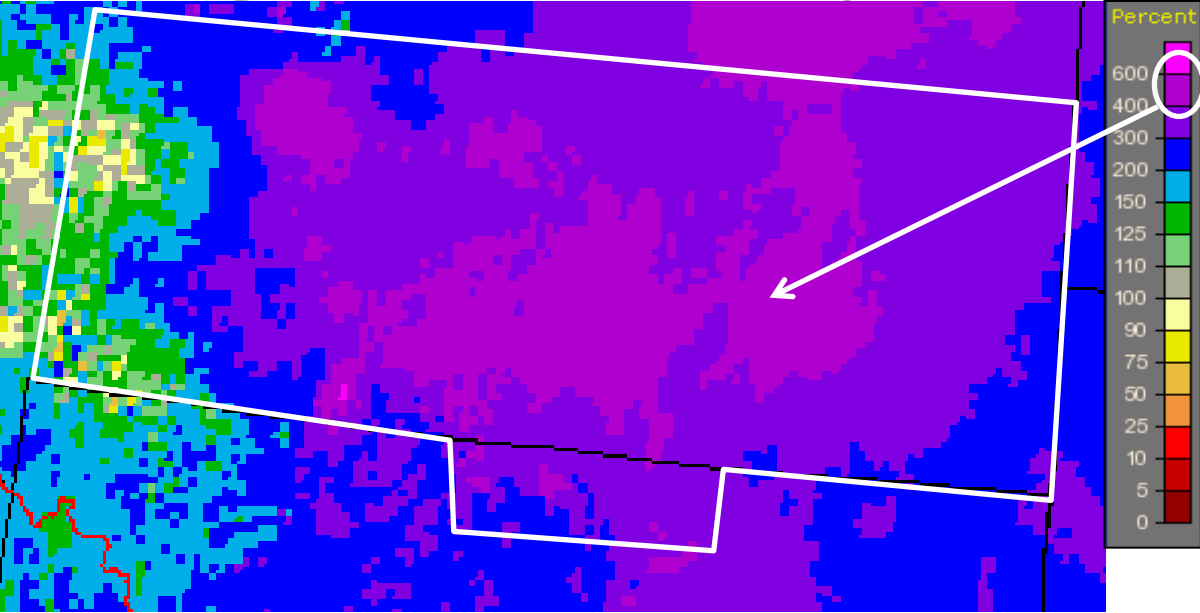
# Heavy Spring Rainfall

## How Heavy Was It?

Photo: Billings Gazette



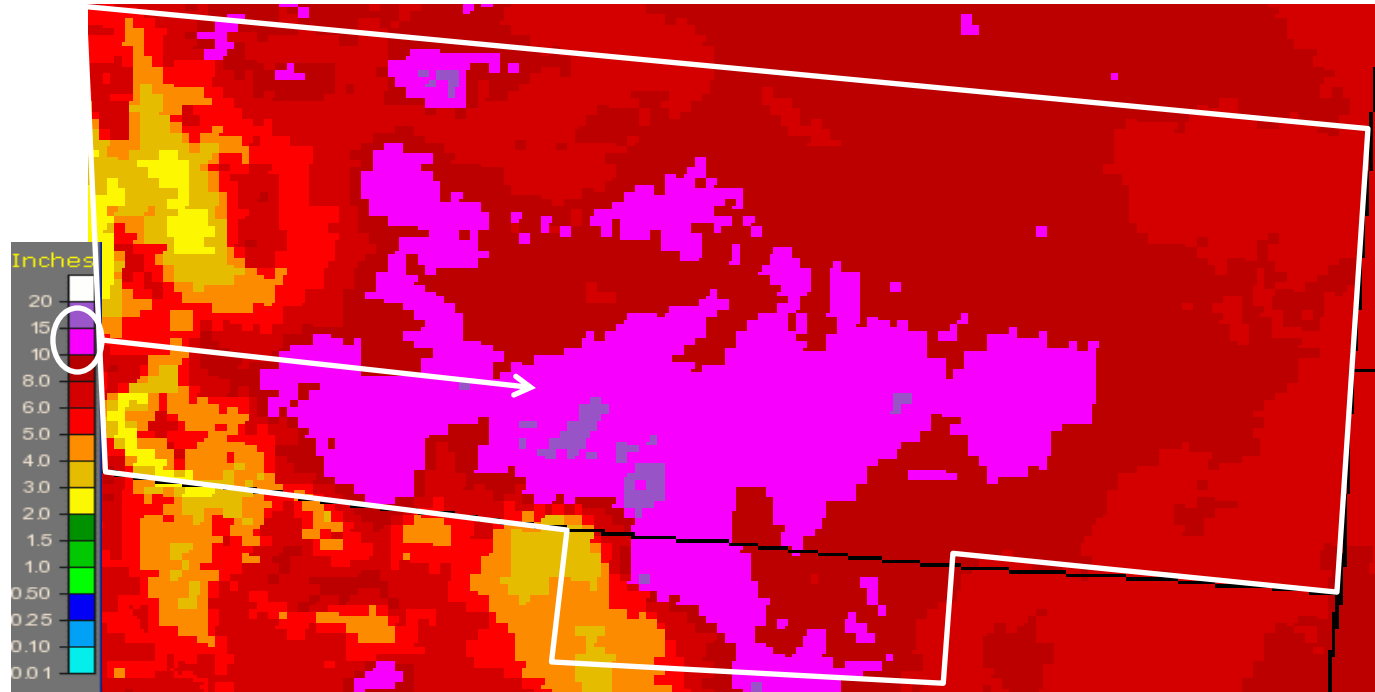
NWS Billings Area – Percent Normal Precipitation



# May 2011 Precipitation

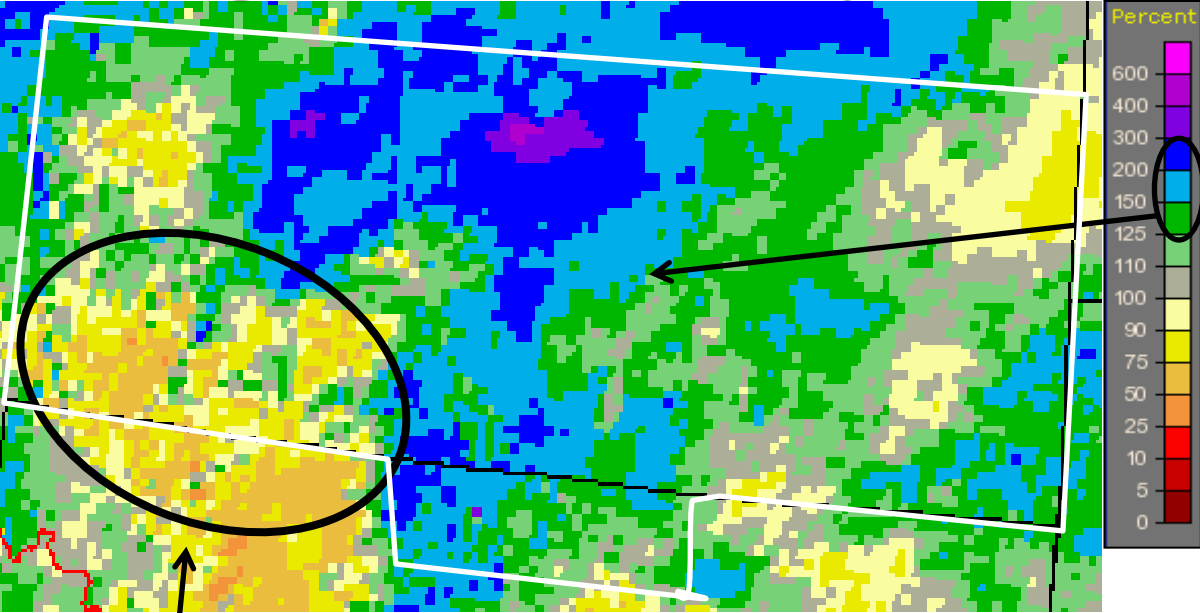
Widespread 400-600 Percent  
Above Normal Precipitation

NWS Billings Area – Precipitation Accumulation



Widespread 10 to 15 inch  
Accumulations  
(Yearly Precipitation Is  
Around 13 inches)

NWS Billings Area – Percent Normal Precipitation



# *June 2011 Precipitation*

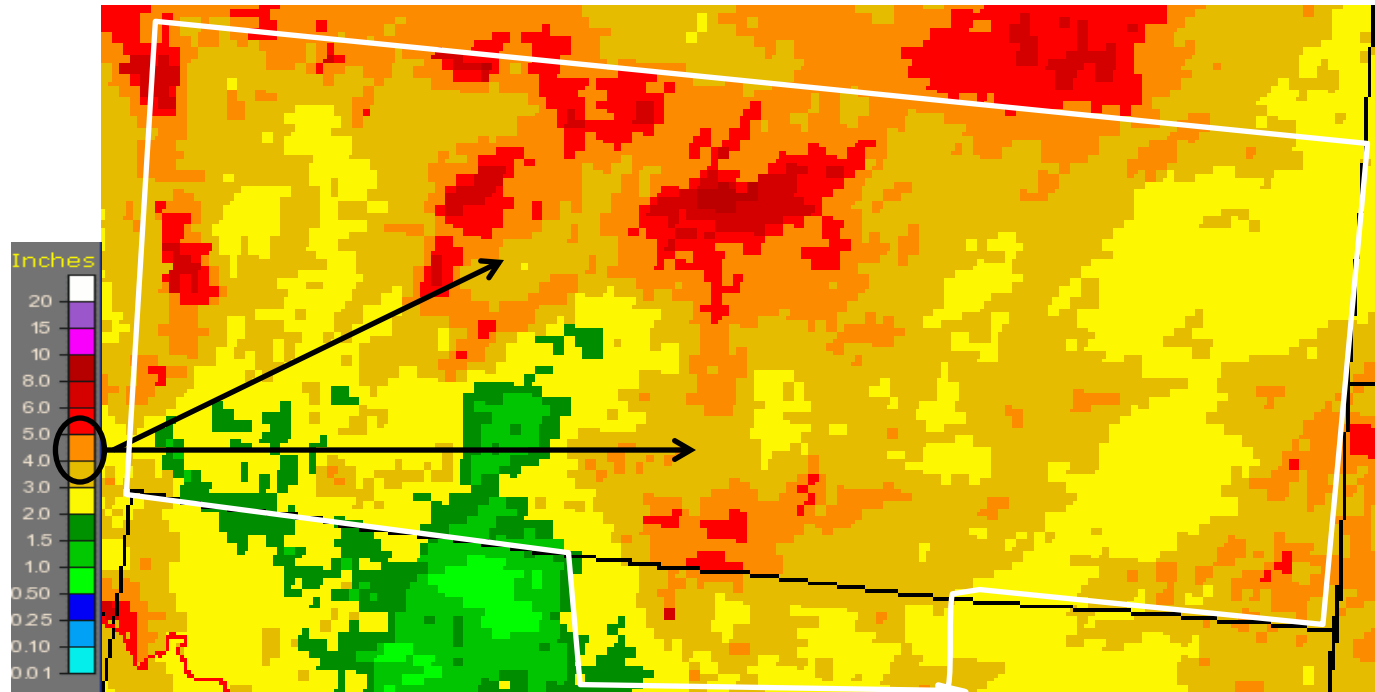
**Widespread 125-300  
Percent Above Normal  
Precipitation**

**Saving Grace :  
Mountains Dried  
out in June**

**Widespread 3 to 6 inch  
Accumulations**

MBRFC Data

NWS Billings Area – Precipitation Accumulation



A photograph of a winter landscape. The ground is covered in a thick layer of snow. In the background, there is a small, light-colored building with a dark roof. To the right, a portion of a larger wooden building is visible. A large, dark, rounded object, possibly a rock or a large log, is partially covered in snow in the foreground. The sky is overcast and grey. The text "Late Snowmelt" and "How Late Was It?" is overlaid on the image in a white, bold, sans-serif font.

# Late Snowmelt

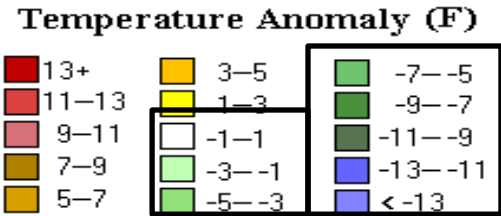
## How Late Was It?

**NWS Billings Area – Temperature Anomaly**

Mountains up to 7  
degrees below average

***May 2011  
Temperatures***

7 to Greater than 13 degrees  
Below Average Lower Elevations

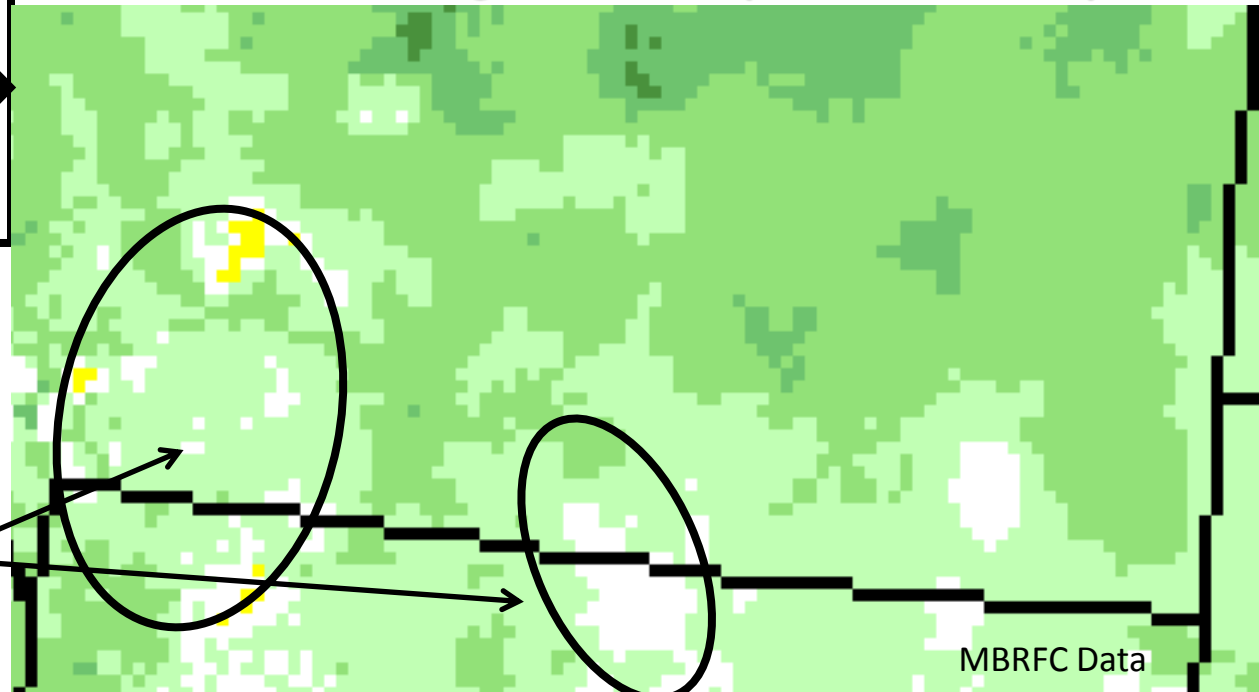


***June 2011  
Temperatures***

June Temperatures Still 3 to 7  
Degrees Below Average  
Lower Elevations

Mountains Warming to Near  
Seasonal Normals, Snowpack  
Beginning to Melt Out.

**NWS Billings Area – Temperature Anomaly**





# Basin Snowpack Average

**April 1<sup>st</sup>**

UPPER YELLOWSTONE RIVER BASIN % Apr 1/% Avg Peak		
Basin-wide percent of average	119	109
WIND RIVER BASIN (WYOMING)		
Basin-wide percent of average	104	95
SHOSHONE RIVER BASIN (WYOMING)		
Basin-wide percent of average	111	102
BIGHORN RIVER BASIN (WYOMING)		
Basin-wide percent of average	113	102
TONGUE RIVER BASIN (WYOMING)		
Basin-wide percent of average	108	95
POWDER RIVER BASIN (WYOMING)		
Basin-wide percent of average	117	102
LOWER YELLOWSTONE RIVER BASIN		
Basin-wide percent of average	109	98

% Change



**+104%**

**+206%**

**+81%**

**+153%**

**Big Horn Mtns**

**+430%**

**+499%**

**+199%**

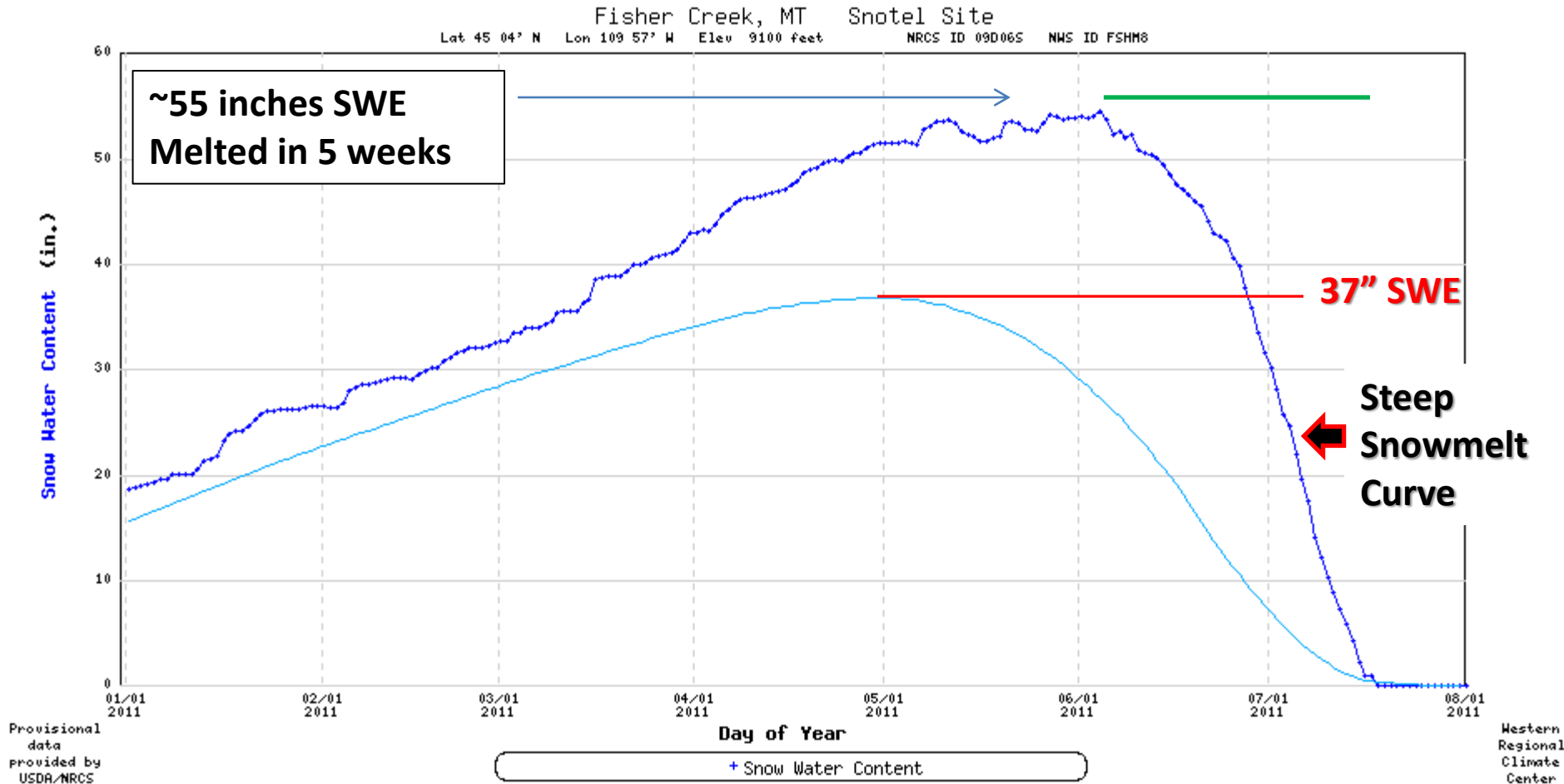
**June 1<sup>st</sup>**

NRCS Data

UPPER YELLOWSTONE RIVER BASIN % Jun 1/% Avg Peak		
Basin-wide percent of average	222	115
WIND RIVER BASIN (WYOMING)		
Basin-wide percent of average	310	120
SHOSHONE RIVER BASIN (WYOMING)		
Basin-wide percent of average	192	114
BIGHORN RIVER BASIN (WYOMING)		
Basin-wide percent of average	266	129
TONGUE RIVER BASIN (WYOMING)		
Basin-wide percent of average	538	140
POWDER RIVER BASIN (WYOMING)		
Basin-wide percent of average	616	137
LOWER YELLOWSTONE RIVER BASIN		
Basin-wide percent of average	308	128

# Fisher Creek SNOTEL

## Feeds the Clarks Fork of the Yellowstone River

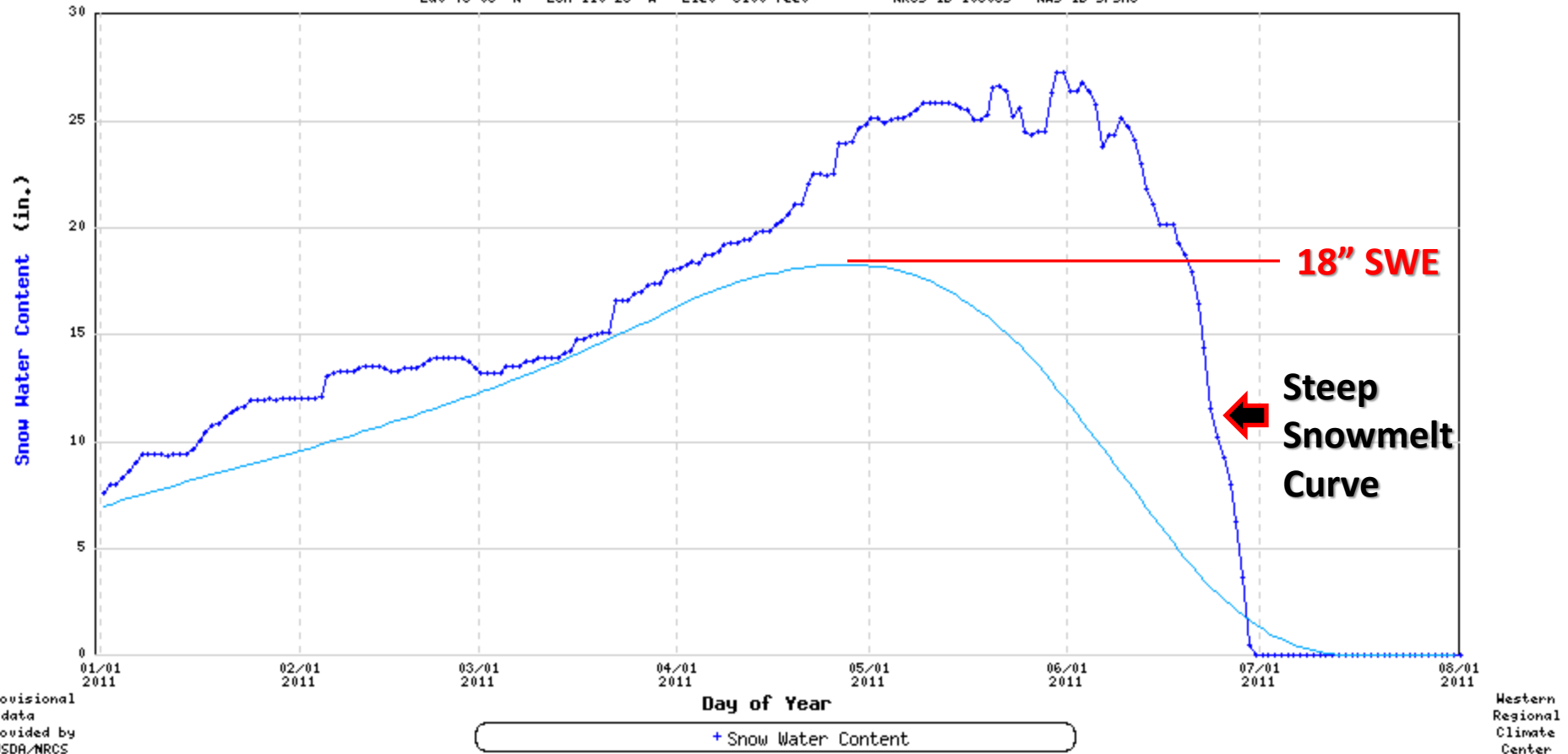


Normal SWE Peak ~ May 1<sup>st</sup> → 2011 ~ June 5<sup>th</sup>  
Normal 37" SWE ~ May 1<sup>st</sup> → 2011 ~ June 27<sup>th</sup>

# South Fork Shields SNOTEL

## Feeds Shields River

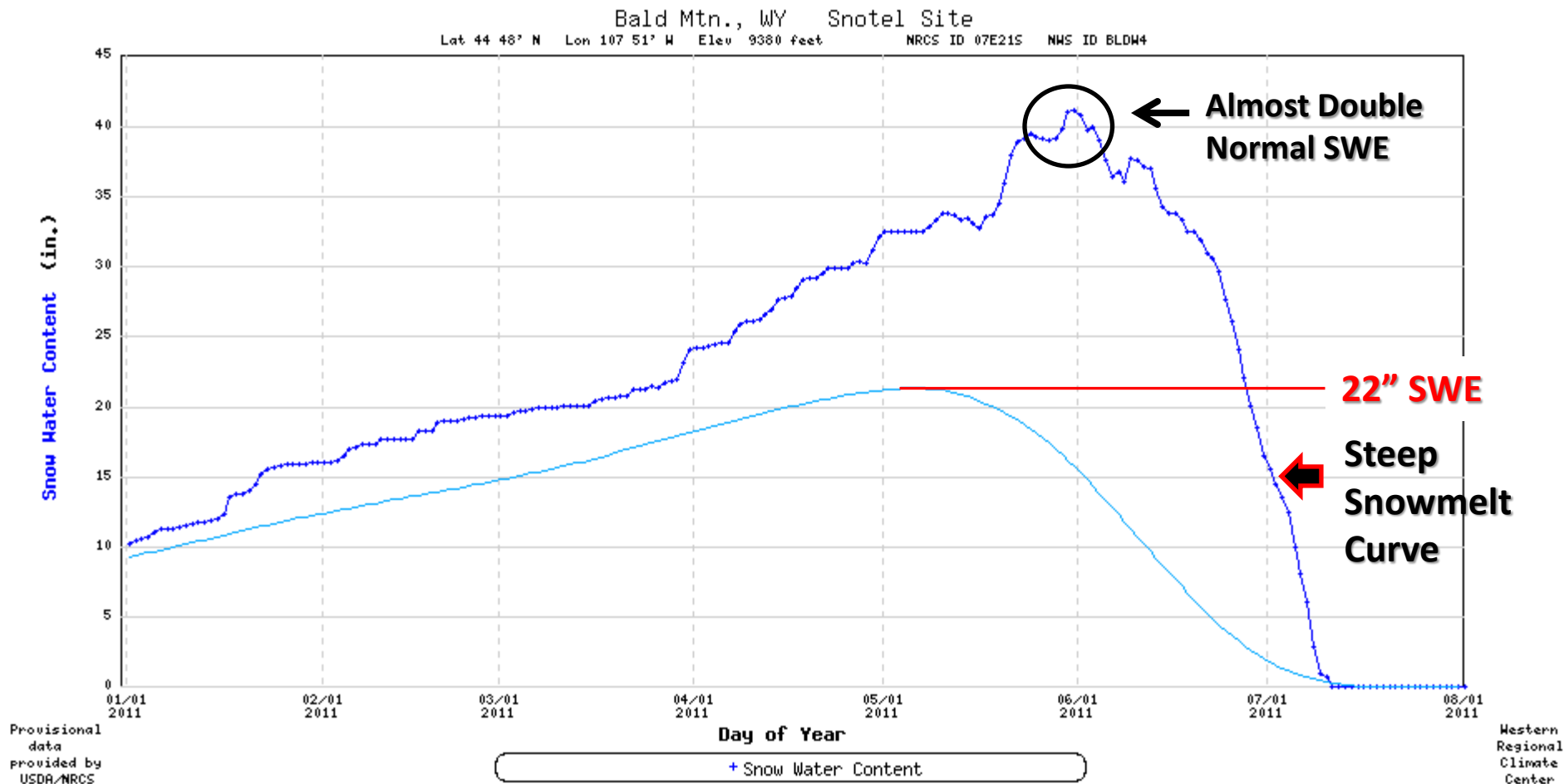
S Fork Shields, MT Snotel Site  
Lat 46 05' N Lon 110 26' W Elev 8100 feet NRCS ID 10C08S NWS ID SFSM8



Normal Peak SWE ~ Apr 28th → 2011 ~ May 29th  
Normal 18" SWE ~ Apr 28th → 2011 ~ June 19th

# Bald Mountain SNOTEL

## Feeds Big Horn River abv Yellowtail Dam

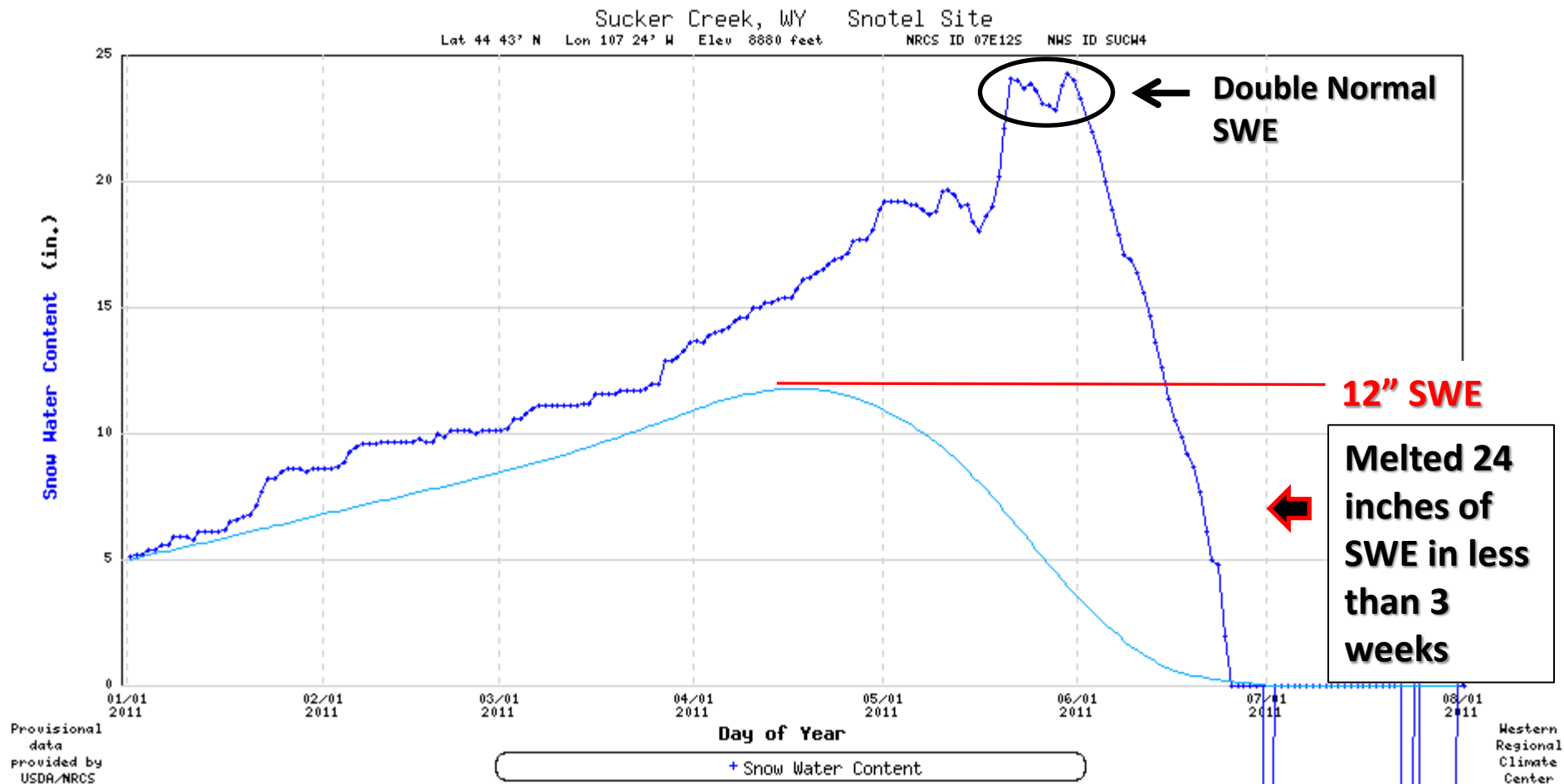


Normal Peak SWE ~ May 7<sup>th</sup> → 2011 ~ June 1<sup>st</sup>  
Normal 22" SWE ~ May 7<sup>th</sup> → 2011 ~ June 27<sup>th</sup>



# Sucker Creek SNOTEL

## Feeds Tongue River



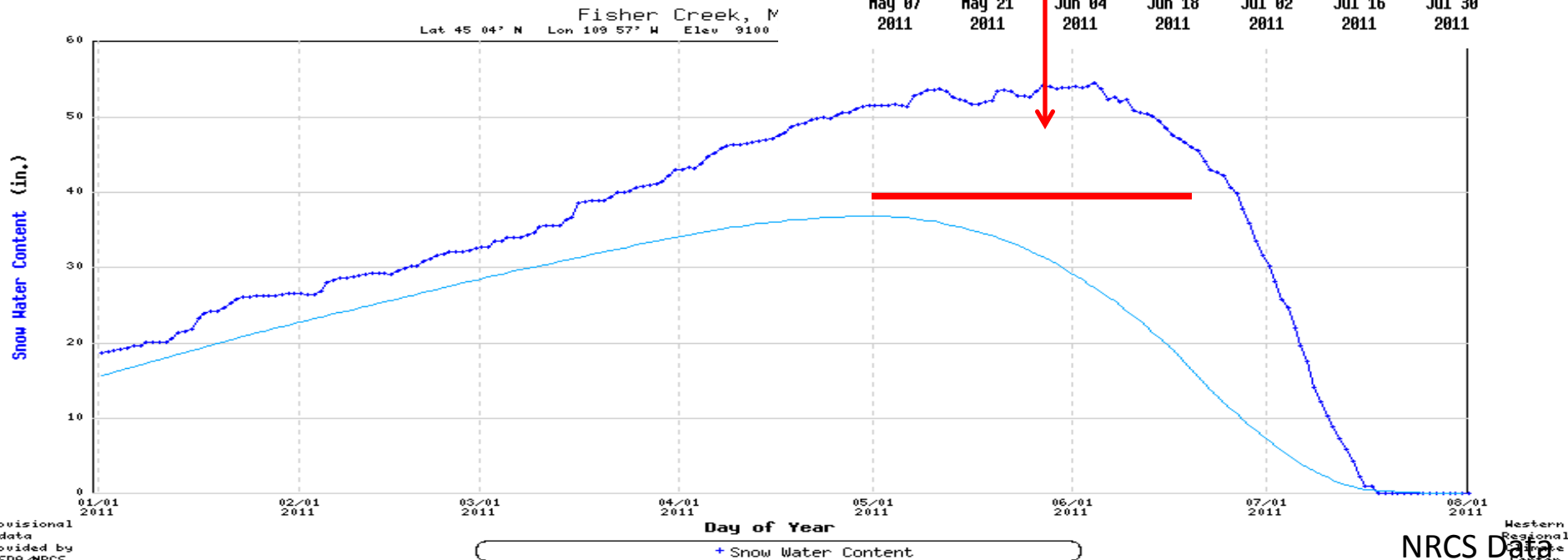
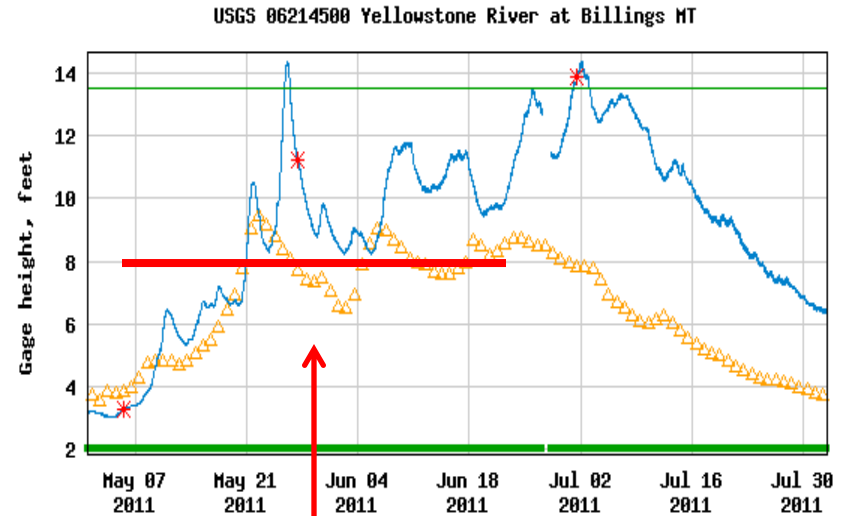
Normal Peak SWE ~ Apr 21st → 2011 ~ May 29th  
Normal 12" SWE ~ Apr 21<sup>st</sup> → 2011 ~ June 15th

# When is Late Snowmelt A Blessing?

**Imagine 50+ inches of Snow Water Melting Out at the Usual Time of Year?!?**

**Recipe for widespread Catastrophic Flooding!**

**Frozen Mountain into June helped limit flooding.**



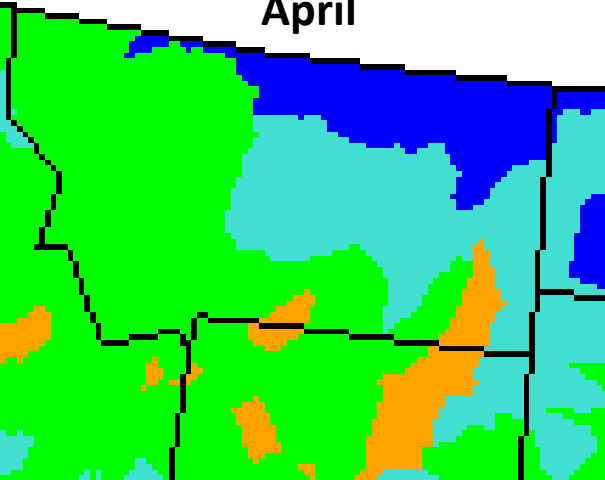


**How Bad Did It Get?**

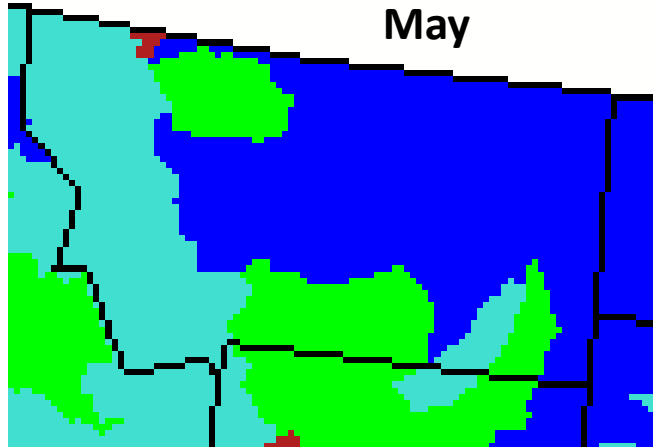
# USGS Monthly Average Streamflow

## April-September 2011

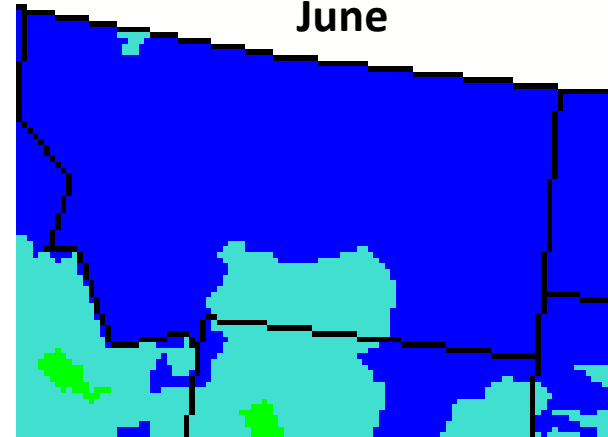
April



May



June

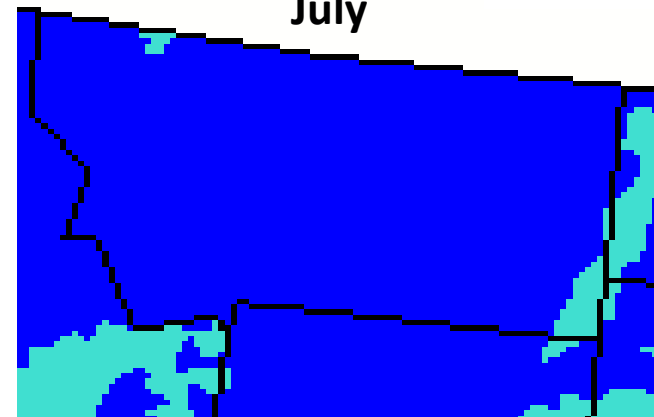


Explanation - Percentile classes

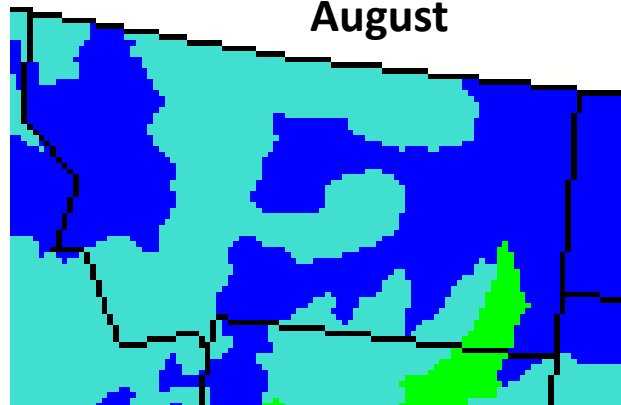
Explanation - Percentile classes							
Low	<10	10-24	25-75	76-90	>90	High	No Data
	Much below normal	Below normal	Normal	Above normal	Much above normal		



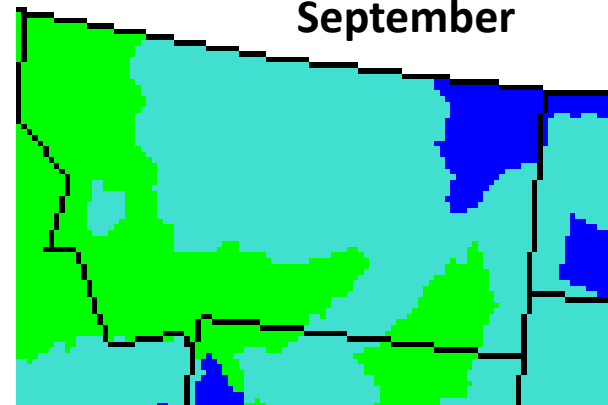
July



August

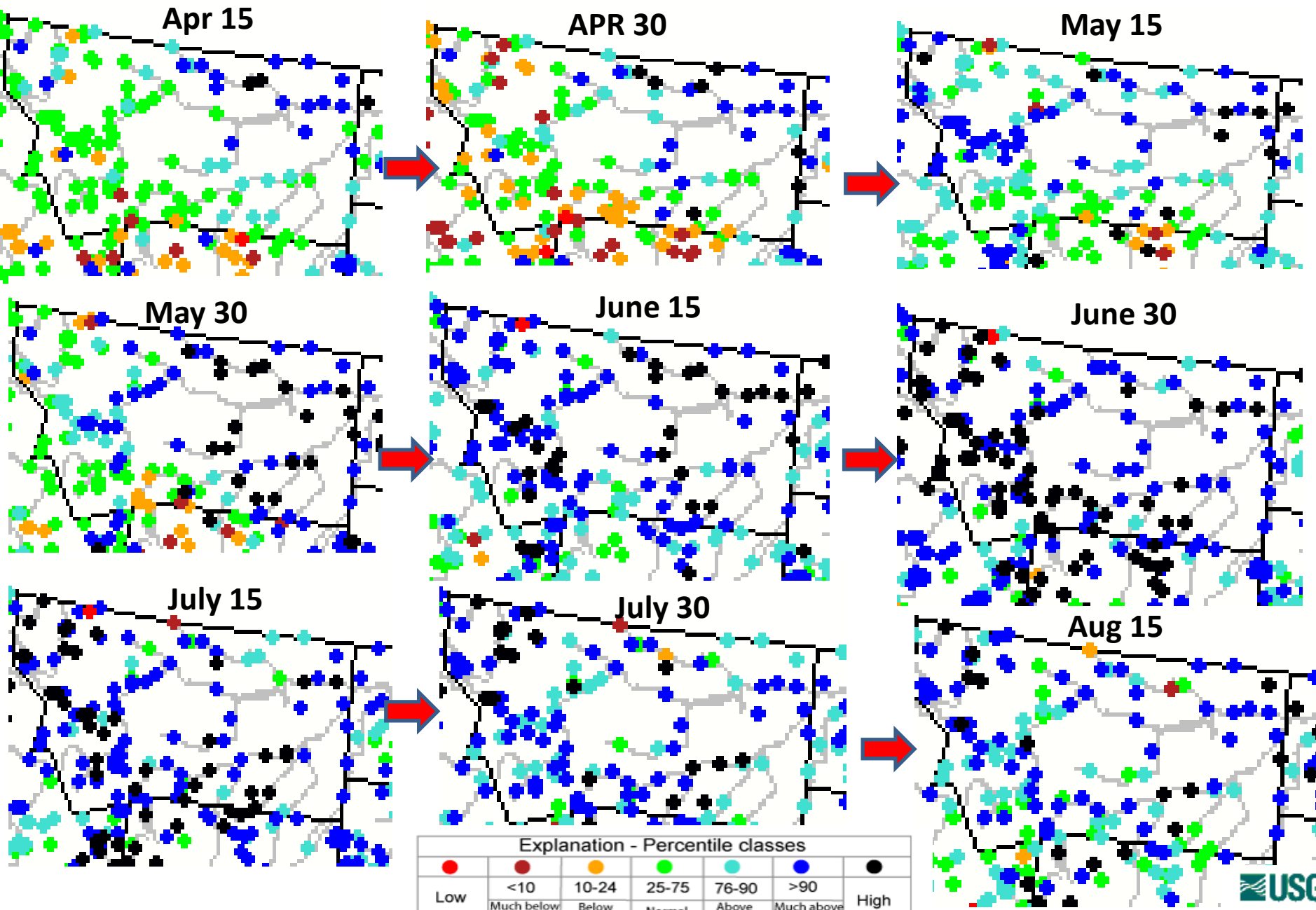


September

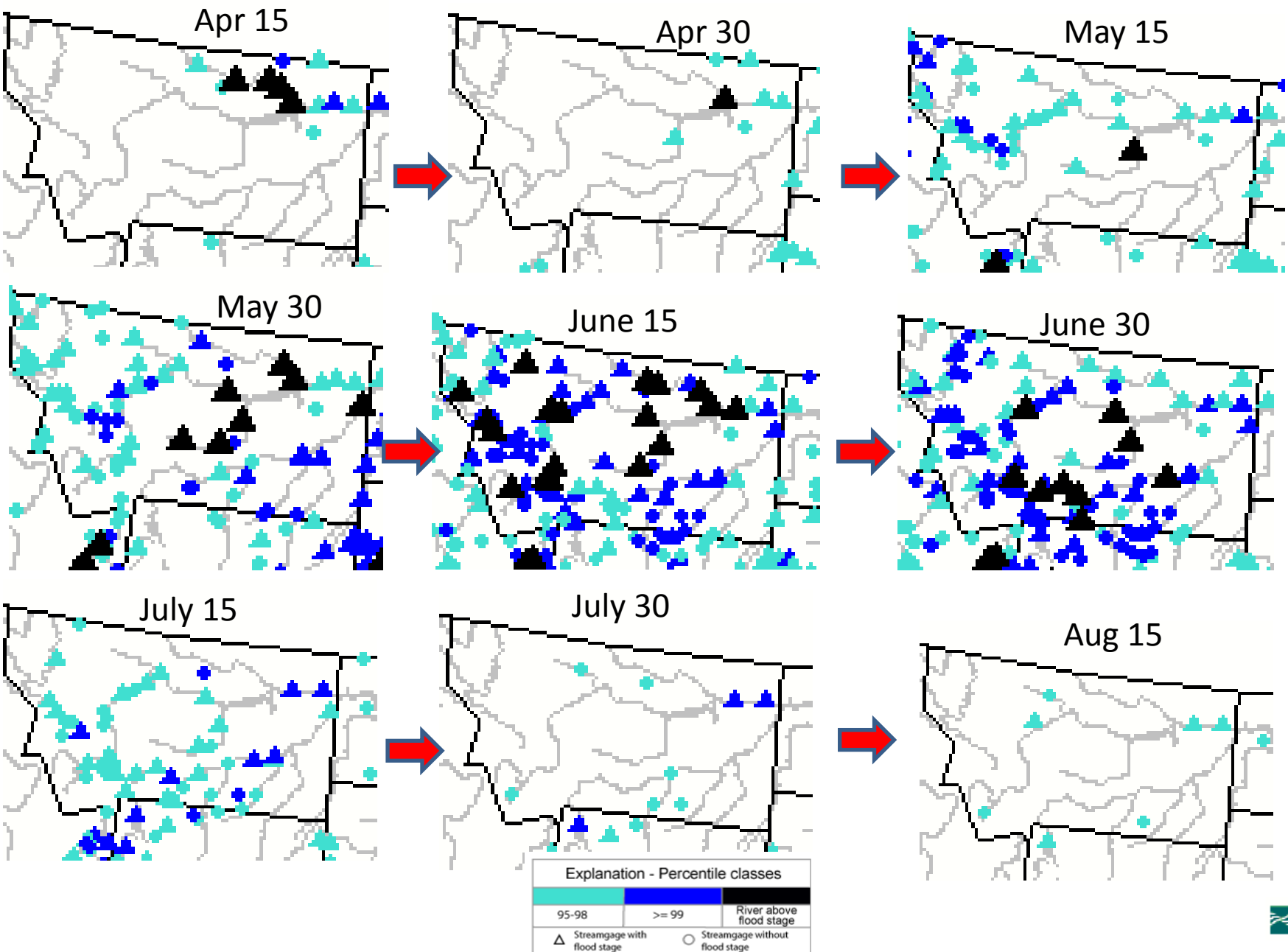




# Streamflow Time Series Apr-Aug



# Stream Gages Reporting >95<sup>th</sup> Percentile Reading



# Flood Stats for Area Gages 5/1-8/1

## Affected Area Summary of Recent Flood and High Flow Conditions

(2011-05-01 -- 2011-08-01)

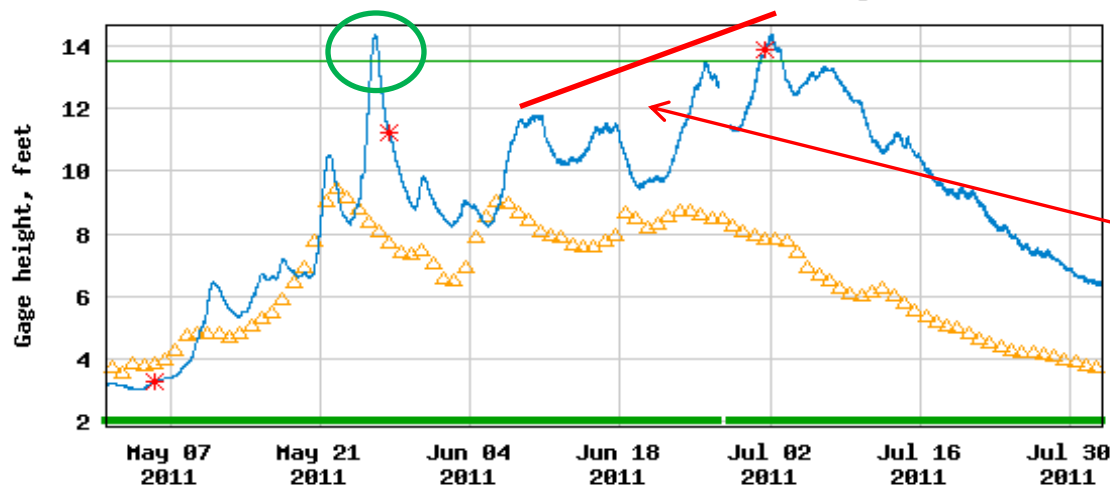
Period :	2011-05-01 -- 2011-08-01
No. of days of the period:	93
Affected Area:	SW: 44.73,-110.81, NE: 46.64,-104.12
Total number of streamgages:	53
No. of streamgages with flood stages:	27
No. of streamgages above flood stage:	20
Max. no. of days above flood stage of a site (06123030):	37
No. of streamgages with moderate flood stages:	26
No. of streamgages above moderate flood stage:	14
Max. no. of days above moderate flood stage of a site (06123030):	28
No. of streamgages with major flood stages:	26
No. of streamgages above major flood stage:	8
Max. no. of days above major flood stage of a site (06126050):	19
No. of streamgages with highest peaks:	0

Musselshell R.  
@ Shawmut

20 of 27 gages with  
established Flood Stage  
went above FS

# Yellowstone River @ Billings

USGS 06214500 Yellowstone River at Billings MT



- Rainfall Peak

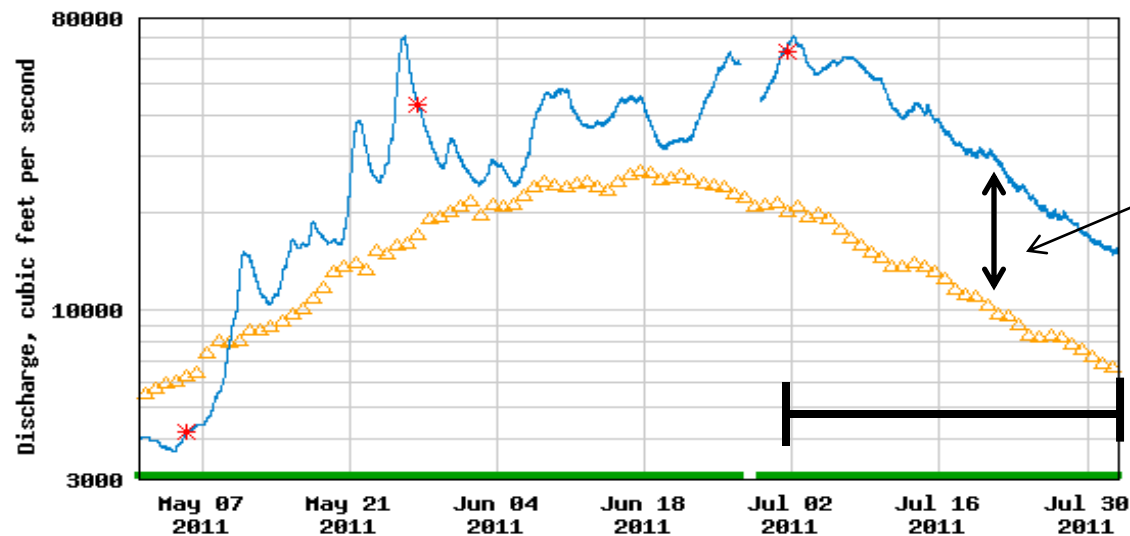
Increasing Snowmelt Contribution 2<sup>nd</sup> week in June to Peak First week of July

△ Median daily statistic (5 years)

— Gage height

\* Measured gage height

USGS 06214500 Yellowstone River at Billings MT



+ 20,000 cfs 3<sup>rd</sup> week July

A lot of river use during this time frame due to Silvertip Pipeline Oil Spill on Yellowstone

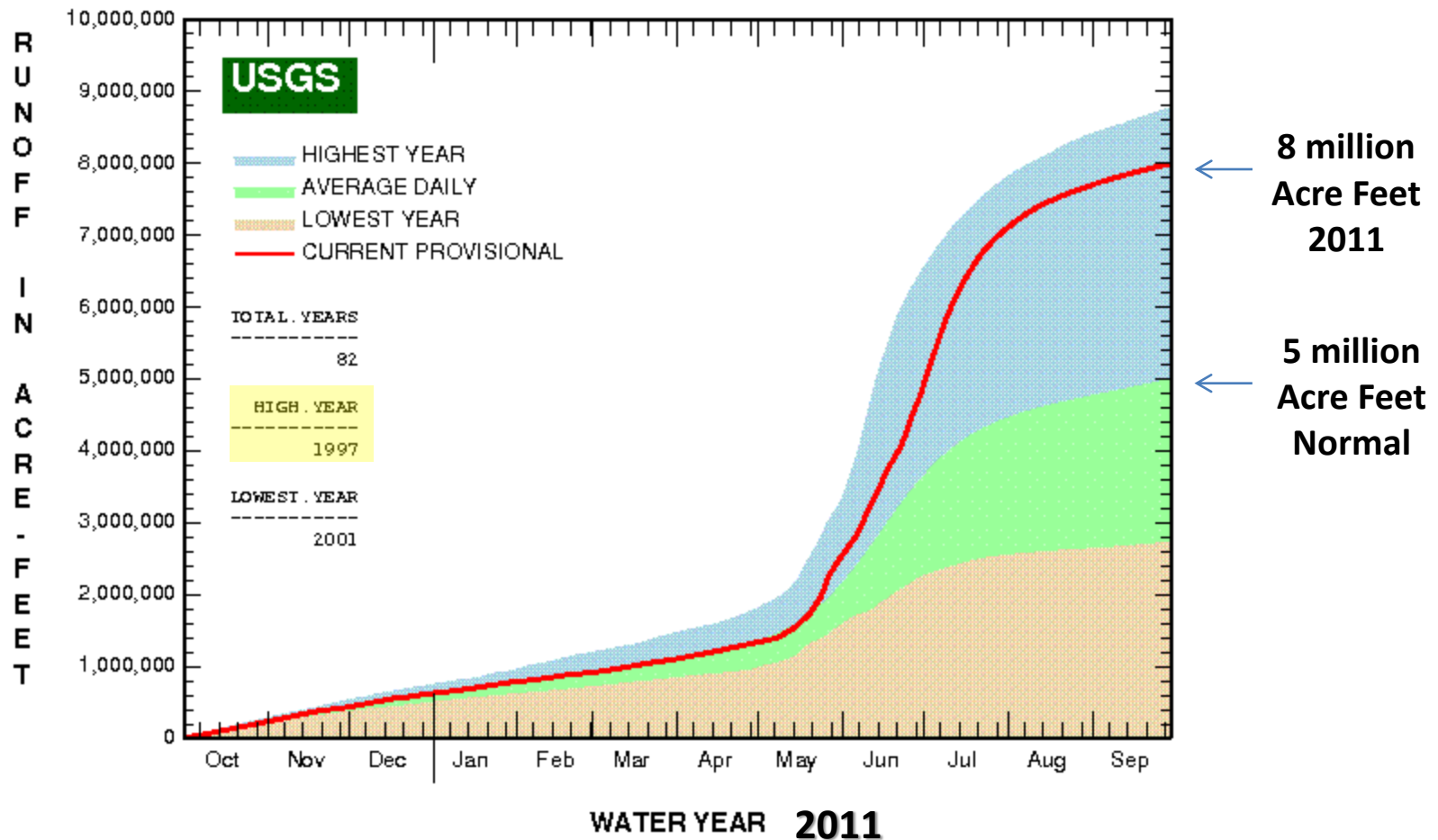
△ Median daily statistic (83 years)

\* Measured discharge

— Discharge

— Period of approved data

# Cumulative Flow Yellowstone River @ Billings 2011

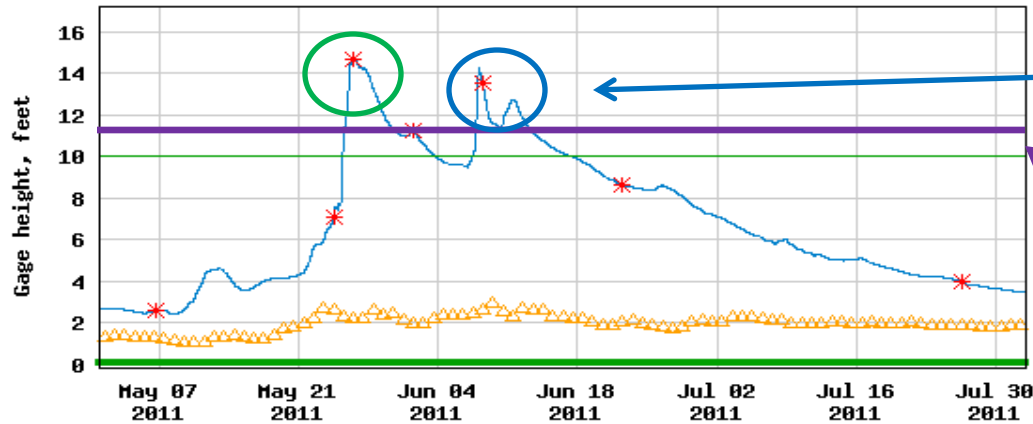


Yellowstone River at Billings MT



# Musselshell River @ Roundup

USGS 06126500 Musselshell River near Roundup MT

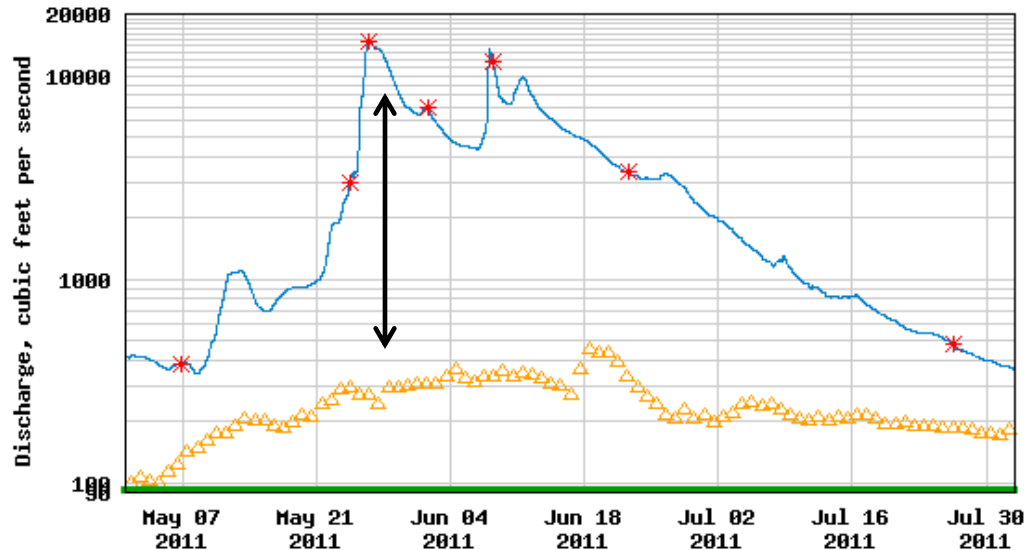


△ Median daily statistic (7 years)  
— Gage height  
\* Measured gage height

Rain Peak in  
Green/Snowmelt aided  
2<sup>nd</sup> Peak in Blue.

Major Flood Stage 11  
feet – Parts of  
Roundup underwater  
off and on for 3 weeks

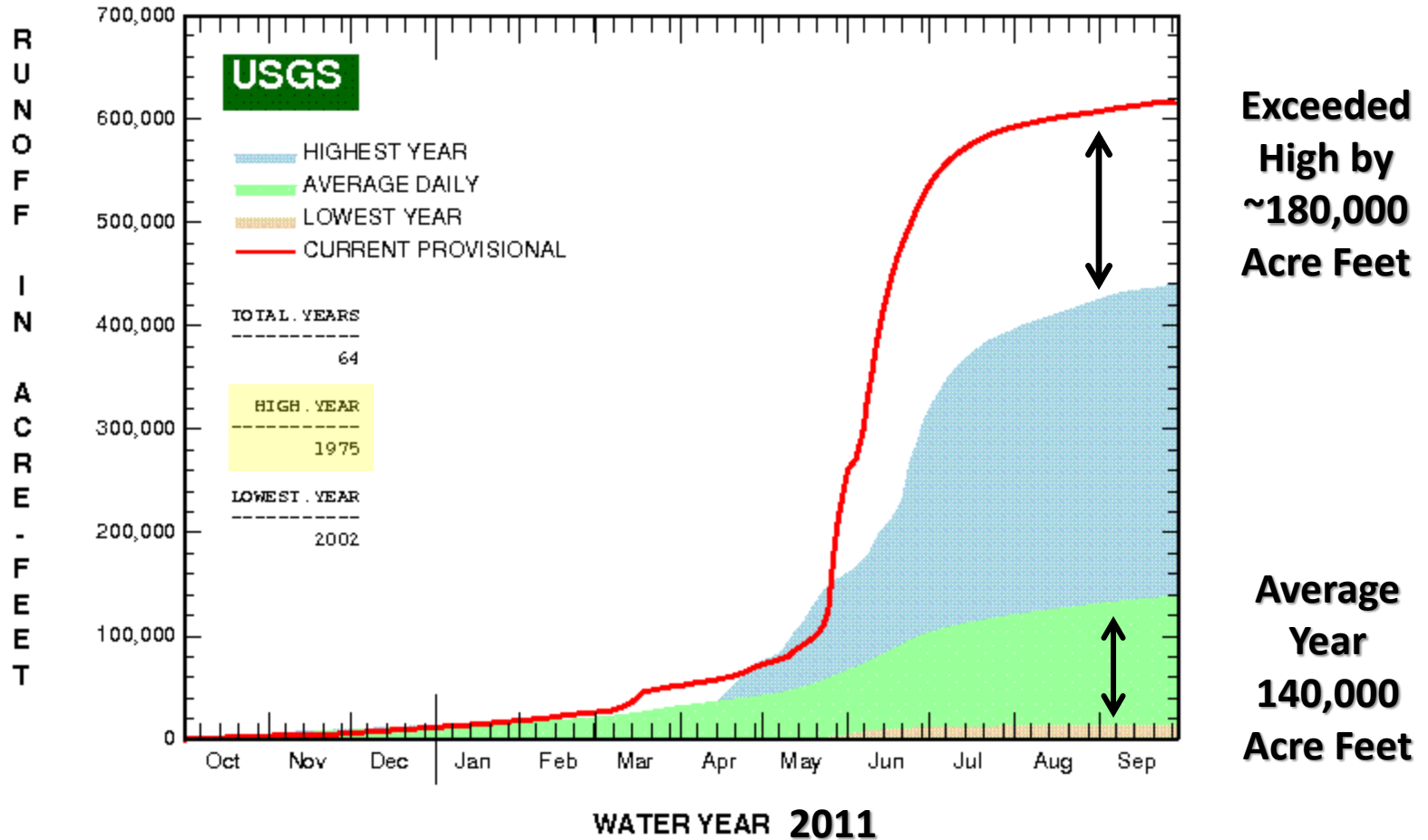
USGS 06126500 Musselshell River near Roundup MT



△ Median daily statistic (65 years) \* Measured discharge  
— Discharge  
— Period of approved data

Flow almost 2  
orders of magnitude  
higher than normal

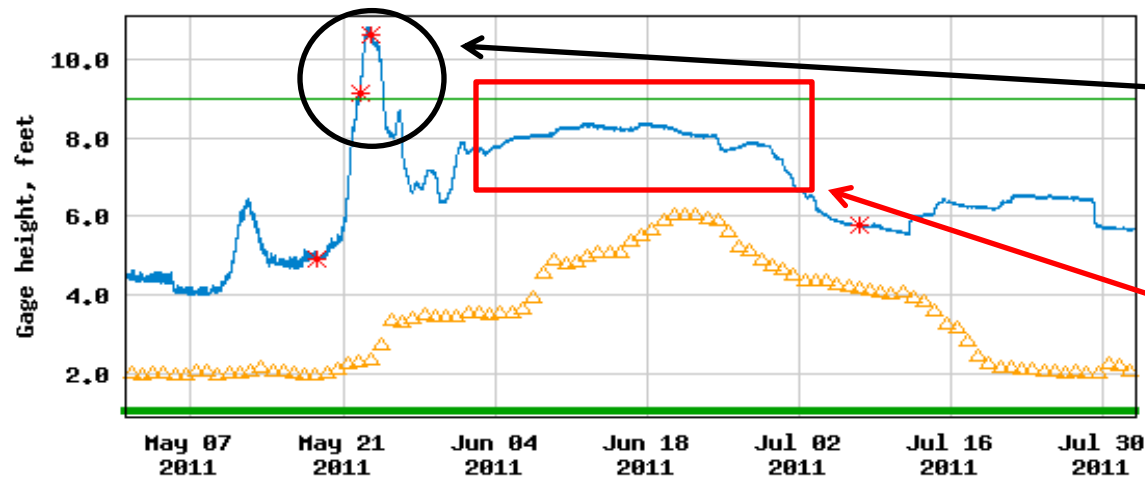
# 2011 Cumulative Flow Musselshell River @ Roundup 2011



Musselshell River near Roundup MT

# Big Horn River near Big Horn

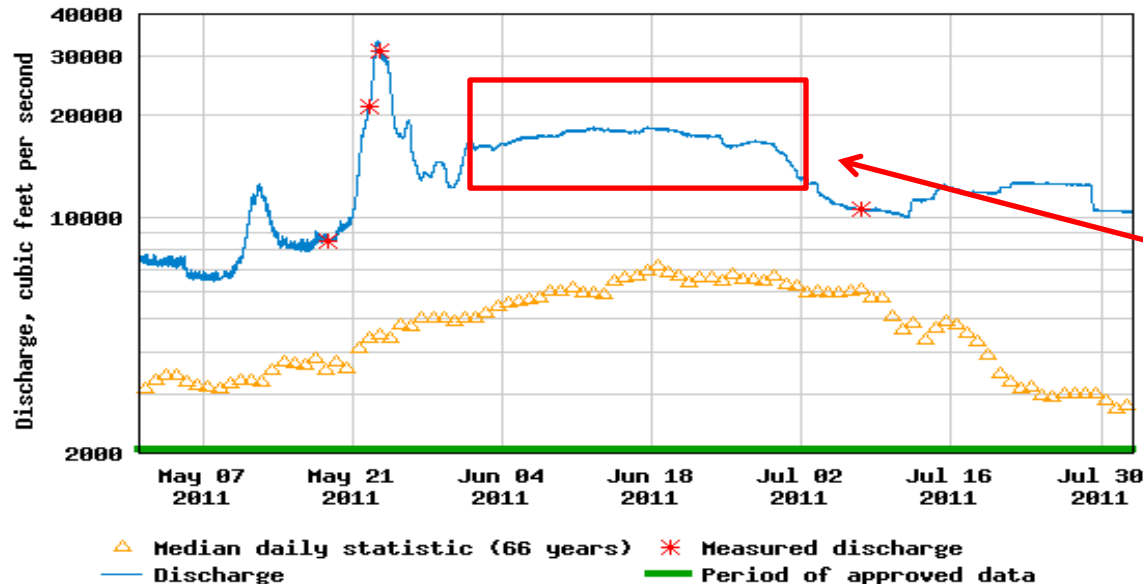
USGS 06294500 Bighorn River ab Tullock Cr nr Bighorn MT



Peak Result of Rainfall  
Downstream of  
Yellowtail Dam

Yellowtail Dam  
Controlling Flows Here

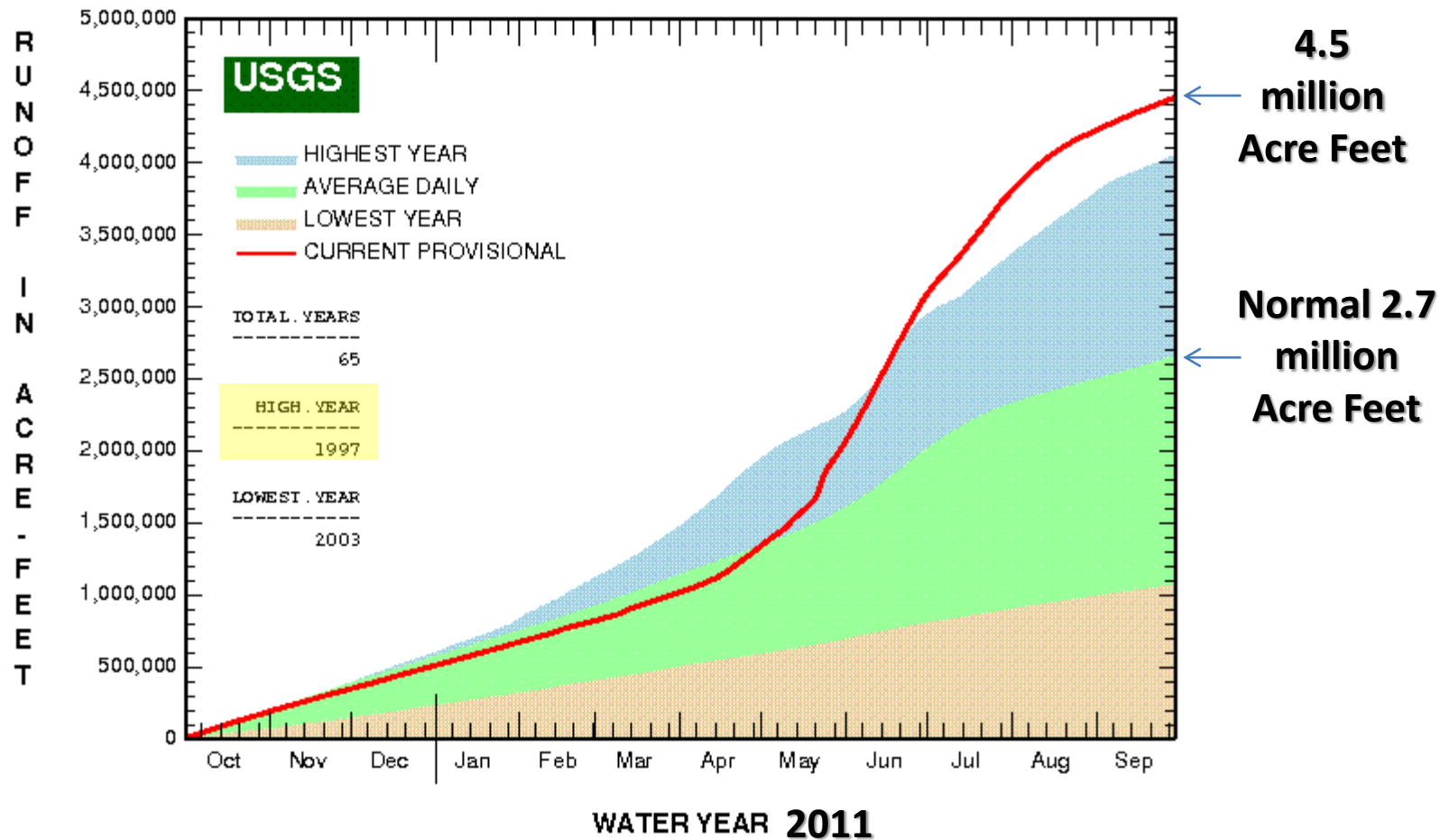
USGS 06294500 Bighorn River ab Tullock Cr nr Bighorn MT



Normal Peak Flow 6-7 kcfs

Flow held at 18-19 kcfs for a  
month

# Big Horn River near Bighorn



Bighorn River ab Tullock Cr nr Bighorn MT

# Impacts





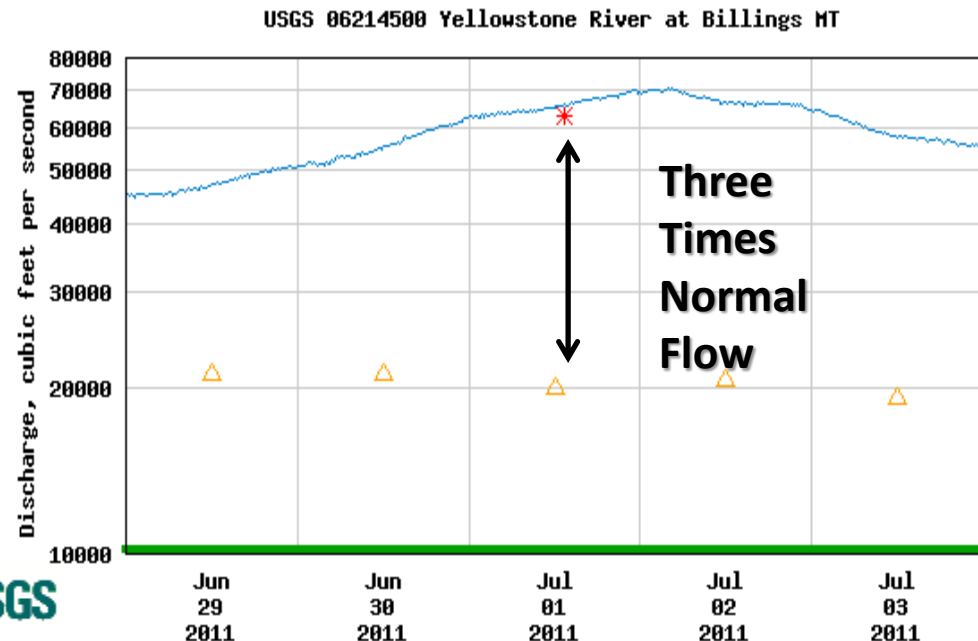
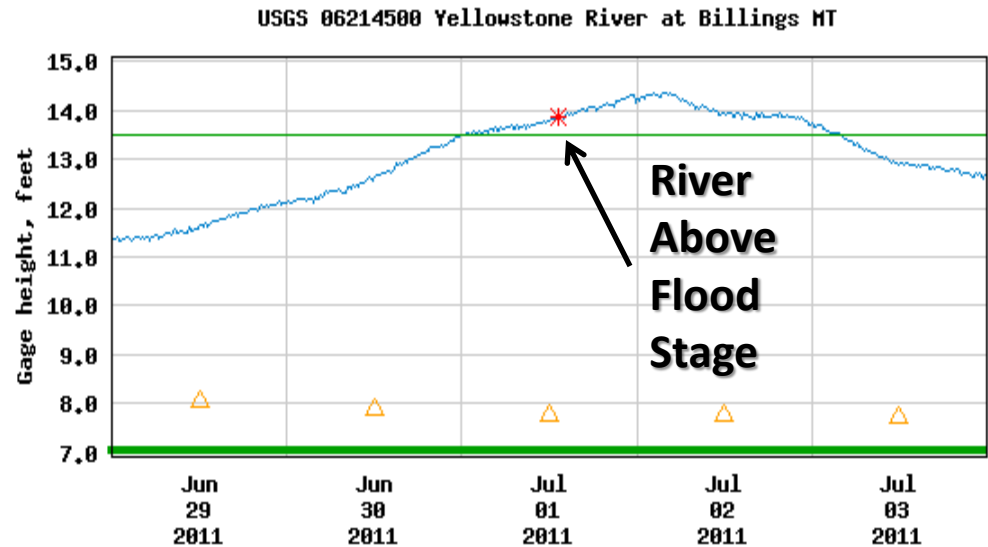
USGS station name	Drain. area [mi <sup>2</sup> ]	NWS flood stage [ft]	No. of days above flood stage	NWS flood class	Highest peak from 2011-05-01 to 2011-08-01				Historical Peaks	
					Date	Stage [ft]	Stream flow [ft <sup>3</sup> /s]	Rank	No. of years	Max. (year) [ft <sup>3</sup> /s]
Musselshell River ab Mud Cr nr Shawmut MT	1513	6.5	37	▲	2011-05-26	9.27	8900	2	14	8900 (2011)
Musselshell River near Lavina MT	2970	8.5	35	▲	2011-05-25	13.95	14500	2	20	14500 (2011)
Tongue R at Birney Day School Br nr Birney MT	2621	6	32	▲	2011-06-12	7.3	4430	4	32	5340 (2007)
Yellowstone River at Miles City MT	48253	13	30	▲	2011-05-24	14.74	85400	4	84	102000 (1978)
Musselshell River at Musselshell MT	4568	11	27	▲	2011-05-27	13.23	16200	2	66	16200 (2011)
Musselshell River near Roundup MT	4023	10	21	▲	2011-05-26	14.78	15000	2	65	15000 (2011)
Musselshell River at Harlowton MT	1125	7	19	▲	2011-05-25	10.25	5520	3	103	7270 (1975)
Clarks Fork Yellowstone River at Edgar MT	2022	8.5	11	▲	2011-07-06	9.27	10700	6	72	11100 (1997)
Yellowstone River near Livingston MT	3551	9.5	10	▲	2011-06-30	10.15	40600	2	87	40600 (2011)
Clarks Fork Yellowstone River nr Belfry MT	1134	8	9	▲	2011-07-05	8.68	12300	4	90	14800 (1981)
Boulder River at Big Timber MT	523	7	9	▲	2011-06-30	8.04	9370	5	64	9940 (1997)
Tongue River at Miles City MT	5397	10	8	▲	2011-05-21	13.99	15300	2	70	15300 (2011)
Powder River near Locate MT	13068	9	6	▲	2011-05-21	11.7	24100	6	74	31000 (1943)
Shields River nr Livingston MT	852	5.5	6	▲	2011-05-25	6.36	4360	3	33	5600 (1979)
Little Bighorn River near Hardin MT	1294	8	6	▲	2011-05-23	12.32	17300	3	59	22600 (1978)
Yellowstone River at Billings MT	11805	13.5	6	▲	2011-07-02	14.37	70600	4	86	82000 (1997)
Stillwater River near Absarokee MT	975	6.5	6	▲	2011-06-30	7.01	10500	5	81	12000 (1967)
Rock Creek near Red Lodge MT	105	7.5	4	▲	2011-06-30	7.74	1970	7	63	3110 (1957)
Bighorn River ab Tullock Cr nr Bighorn MT	22414	9	3	▲	2011-05-23	10.86	33200	2	30	33200 (2011)
Pumpkin Creek near Miles City MT	697	13	3	▲	2011-05-20	14.41	7900	2	20	7900 (2011)

## Data For 20 Gage Sites that Exceeded Flood Stage

- 8 Sites Set High Flow Records
- 7 Sites Hit Second or Third Highest
- 12 Sites Hit Peak May 21-26 due to Rainfall
- 7 Sites Hit Peak Late June/July due to Snowmelt
- Only One Hit Record Level due to Snowmelt

# Silvertip Pipeline Break

- Break occurred July 1<sup>st</sup> at around 11 pm.
- 12" Oil pipeline under the Yellowstone River just up river of Billings scoured out and broke.
- Approx. 1500 barrels of heavy crude oil spilled (63000 gallons).
- First question asked of our office..."How fast is it moving downstream and when will it get to my location?"



# Silvertip Spill



Photos from Billings Gazette



# Silvertip Spill

Cleanup initiated during high flows : Dangerous Currents and Floating Debris (Large Cottonwood Trees).



# Silvertip Spill



Photos from Billings Gazette

**Cleanup lasted into  
Winter and cost  
135 million dollars**





# Flooding Impacts



Downtown Roundup  
(Musselshell County)

Convenience Store - Joliet  
(Carbon County)



Bridge/Road Washout  
(Eastern Musselshell County)

Photos from Billings Gazette



# Roundup Flooding

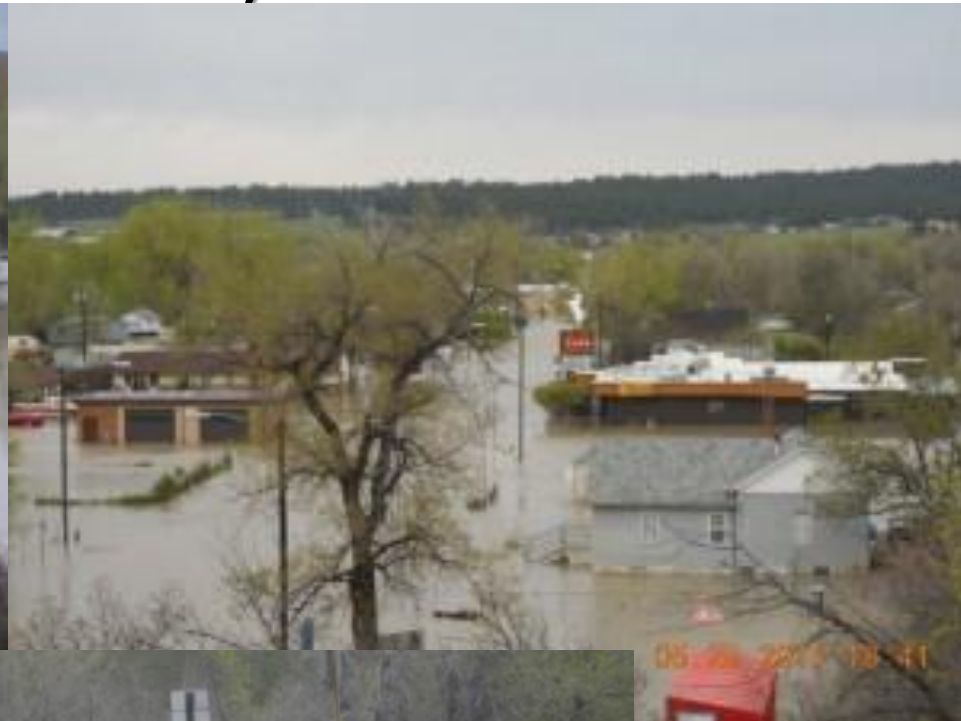
## (Musselshell River)



Photos from Billings Gazette

# Roundup Flooding

## (Musselshell River)



USGS Taking  
Measurement ➡  
...Walking on  
Highway 87

Photos from  
Billings Gazette



# Big Horn County Flooding

## (Big Horn and Little Big Horn Rivers)



← Time to use the boat?



Photos from Billings Gazette

# I-90 Big Horn County Flooding

## (Big Horn and Little Big Horn Rivers)



Photos from Billings Gazette



# Flooding Near Billings



Bozeman Chronicle

← Bridge Washed out on Pryor Creek



Yellowstone River Flooding at Billings →

Billings Gazette

# After Action/Lessons Learned

- Hard to Predict ahead of time how a flood season is going to play out
- May is the critical time frame for flood development
- After Action Meetings (Good / Bad Service)
  - Packets for each county
- MBRFC After Season Meeting
  - Pilot Projects for the MT Offices
    - Requested 5-day QPF forecasts
    - More frequent 90-Day Exceedance Probability Graphics
    - COOP / CoCoRAHS Reporting Times
    - Expanded Forecast Points ... useful/ not useful
    - Use of Ensemble QPF based River Forecasts
- Tailor BYZ Training Plan towards more FEMA-type training to gain important knowledge
- WR IDSS Webinar Team
  - Share our experiences region-wide

# Areas For Research

- Rules of thumb to better connect upstream gage readings to downstream forecasts.
- Improve correlation between radar rainfall rate and localized flood potential.
- Determine usefulness of ensemble QPF River Forecasts.
- Determine what flows correspond to a given downstream speed.

# That's All Folks



## Questions?